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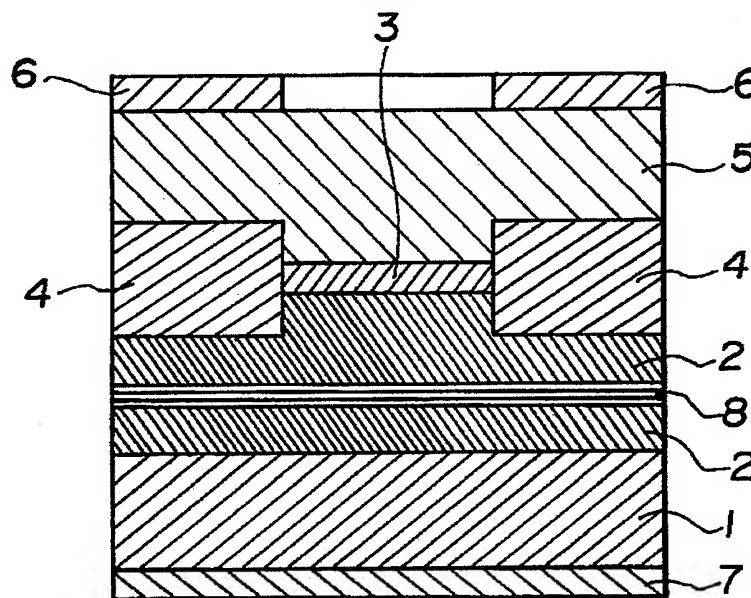
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(54) Light emitting device

(57) The light emitting device comprises a first clad layer 2 and a second clad layer 5 formed successively on a semiconductor substrate 1, an active layer 3 and a current block layer 4 for current constriction both interposed between said first and second clad layers 2, 5 so as to be coplanar, a first electrode 7 formed on the surface of the substrate opposite to the first clad layer 2, and a second electrode 6 formed on the second clad layer 5. The active layer may comprise GaAs and the clad layers AlGaAs. A Bragg reflective layer 8 is disposed within the layer 2 or between the substrate and the layer 2.

FIG.1

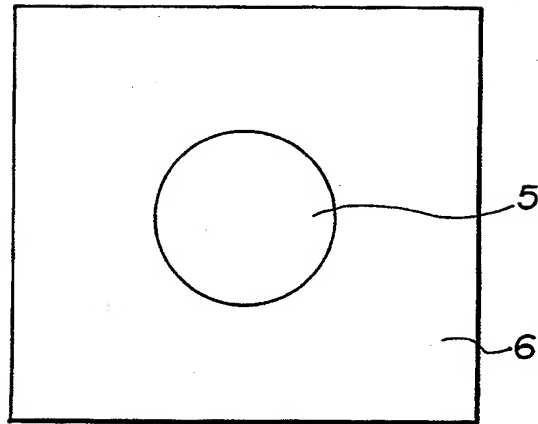
(b)



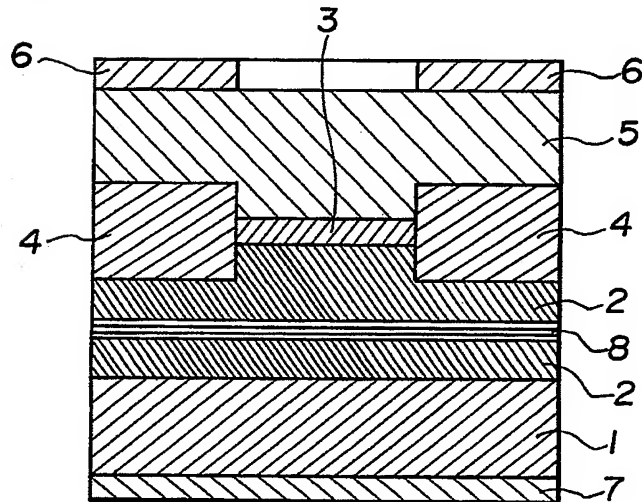
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FIG.1

(a)

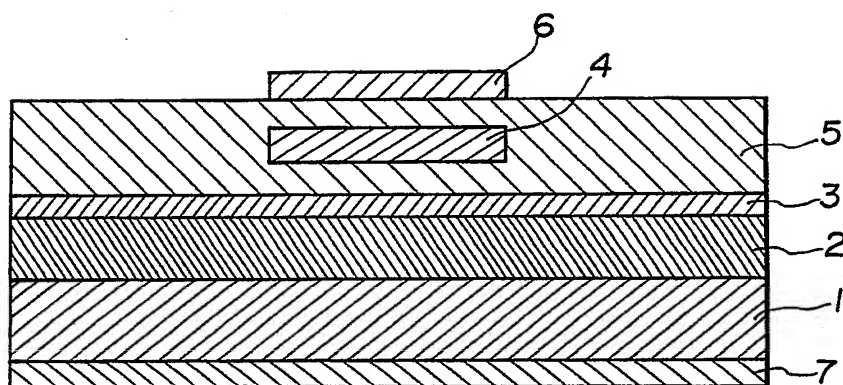


(b)



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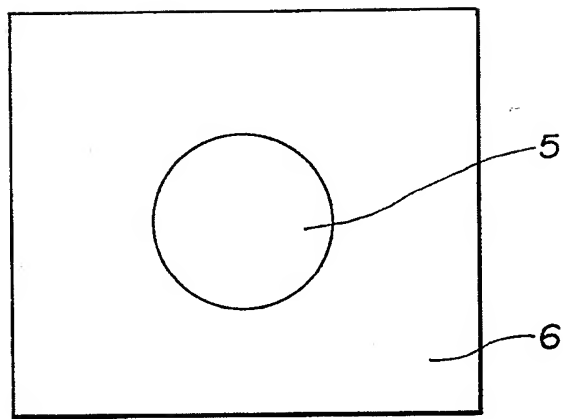
FIG.2



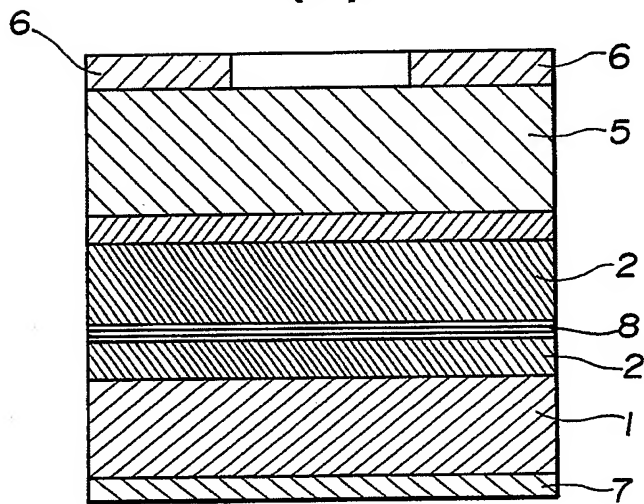
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FIG.3

(a)

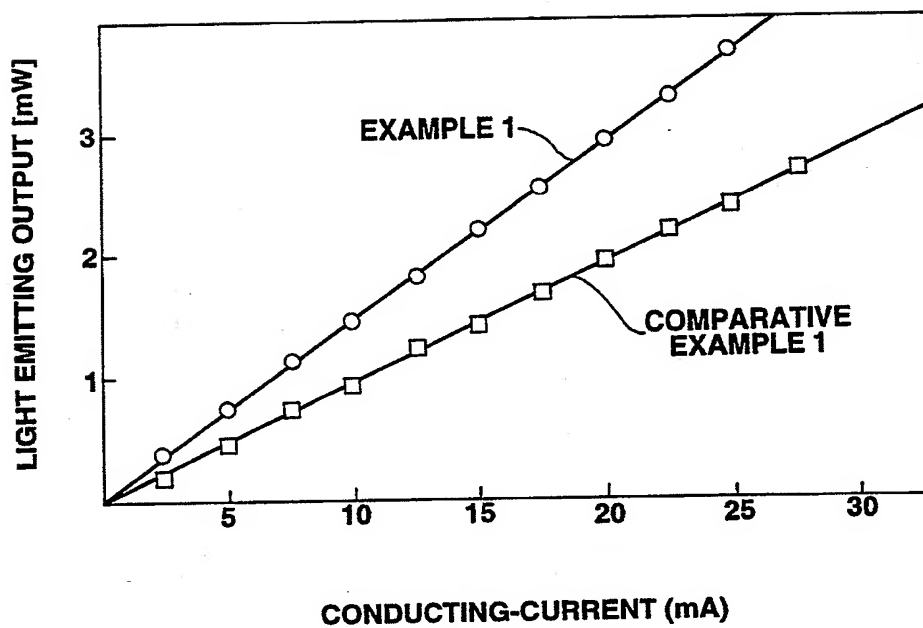


(b)



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FIG.4



LIGHT EMITTING DEVICE

The present invention relates to a light emitting device, and, in particular, it relates a light emitting device with a high light emitting output.

Since light emitting devices consume less electric power and generate less heat, as well as being advantageous for miniaturising products, they have been used in various field of application. However, devices of smaller size and higher light emitting output are demanded.

In view of the above, various methods have been devised in recent years for improving both the efficiency of emission and the output of the light emitting device. For example, there has been adopted a method of disposing a Bragg reflective layer on the side opposite to an active layer, a method of disposing a current block layer (current inhibiting layer) just under an electrode for avoiding the interruption of light emitted from an active layer by the electrode, or a method of applying resin-sealings to suppress loss due to total reflection at the surface of the light emitting device.

For instance, US Patent No. 5,153,889 proposes a semiconductor light emitting device, comprising a semiconductor substrate of a first conductivity type, reflective layer of the first conductivity type formed on

the front surface of the substrate, a transparent buffer layer of the first conductivity type formed on the reflective layer, a double hetero structure portion formed of an InGaAlP series material, positioned on the transparent buffer layer, and consisting of a lower clad layer of the first conductivity type, an upper clad layer of a second conductivity type and an active layer interposed between the lower and upper clad layers, a current spreading layer of the second conductivity type formed on the double hetero structure portion, a first electrode formed on the current spreading layer, a second electrode formed on the back surface of the substrate, and a current inhibiting layer of the first conductivity type formed in a part between the double hetero structure portion and the first electrode in a manner to face the first electrode and disposed just under the first electrode.

One of light emitting devices disclosed in US Patent No. 5,153,889 has a layer structure illustrated as in Fig. 2.

The layer structure shown in Fig. 2 is an example of light emitting devices adapted such that a current block layer 4 is disposed just under an electrode 6 within the second clad layer 5 disposed on an active layer 3, so as to reduce light which can not go out due to interruption by the electrode 6 since emitted just under the electrode 6.

However, it can not still be said that the light

emitting output of the light emitting devices of the prior art is sufficient, and there is still a great demand for the improvement of the light emitting output of the light emitting devices and a further improvement has been desired.

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According to the present invention there is provided a light emitting device comprising a first clad layer and a second clad layer formed successively on a semiconductor substrate, an active layer and a current block layer interposed between said first and 10 second clad layers, said current block layer being disposed in parallel with the active layer at an identical plane with that of the active layer and at least a portion of the periphery of the active layer of current constriction, a first electrode formed on the surface of the substrate opposite to the first clad layer, 15 and an electrode formed on the second clad layer.

Preferably the current block layer is adjacent at least a portion of the periphery of the active layer.

20 Advantageously, the current block layer surrounds the active layer.

The present invention may provide a light emitting device having an improved light emitting output.

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The present invention may provide a light emitting device with an increased current density, a reduced light absorption and a reduced light-reflection as compared with the prior art, and a

remarkably improved brightness as compared with those in the prior arts.

It has been found that by disposing a current block layer and the active layer so as to have a common plane, the light emitting output, for example, brightness of a light emitting device may be remarkably improved.

In order that the invention may be better understood, the following description is given, merely by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is an explanatory view illustrating of a structure of a light emitting device according to the present invention, that is, (a) is the top view thereof and (b) is the cross-sectional view thereof;

Fig. 2 is an explanatory view illustrating of a structure of a light emitting device in the prior art;

Fig. 3 is an explanatory view illustrating of a structure of a light emitting device of Comparative Example 1, that is, (a) is the top view thereof and (b) is the cross-sectional view thereof; and

Fig. 4 is a view illustrating of the relation of light emitting output and conducting-current of light emitting devices between Example 1 and Comparative Example 1.

A light emitting device (herein after referred to as "LED") according to the present invention comprises on a semiconductor substrate 1 a first clad layer 2, an active layer 3, a current block layer 4 disposed to have a common plane (so that they are in parallel and side by side) with the active layer 3 and adjacent to the active layer 3 around at least a portion of a periphery of the active layer 3, a second clad layer 5 and a second electrode 6 formed thereon successively. A first electrode 7 is disposed on the surface of the substrate 1 opposite to the first clad layer.

There is no particular restriction on the material of the LED according to the present invention, but usually a material composed of a Group III-V compound or a Group II-VI compound is used. As the Group III-V compound, a GaAs-based compound or GaP-based compound can be used, and a ZnSe-based compound can be used as the Group II-VI compound.

Now, description will be made to a case of producing an LED having a structure according to the present invention with a Group III-V compound for the sake of convenience, but it will be apparent that the LED can also be produced by other compounds, for example, a Group II-VI compound.

For the substrate 1, a GaAs or GaP substrate is generally used and it has usually an n-type conductivity.

The thickness of the substrate is usually from 50 to 500 μm , preferably from 250 to 380 μm .

The first clad layer, 2 is formed on the substrate 1. The composition of the first clad layer 2 is generally composed of AlGaAs and the conductivity of the first clad layer 2 may be identical with that of the substrate 1. The composition ratio of aluminum and gallium in the first clad layer 2 varies depending on the composition of the active layer 3 and the amount of aluminum in the first clad layer 2 increases as the amount of aluminum in the active layer 3 is greater. A concrete composition thereof may be determined taking a band gap into consideration. The thickness of the first clad layer 2 is usually from 0.1 to 50 μm , preferably from 0.1 to 10 μm . There is particular restriction on a dopant, and selenium, silicon or the like is used as the dopant. Silicon having good controllability for growing is preferred.

In a preferred embodiment of the present invention, a Bragg reflective layer 8 may be disposed within the first clad layer 2 (as shown) or between the substrate 1 and the clad layer 2. The Bragg reflective layer 8 is composed of a laminate made of materials having different refractive indices, which are stacked alternately each at a thickness determined depending on the refractive index and a wavelength of light intended to be reflected. The laminate has a property of reflecting light. Since this laminate

can reflect light on the light take-out side, the luminous efficiency (light emitting efficiency) can be improved.

The thickness of the Bragg reflective layer 6 is less than 50 μm , preferably from 1 to 20 μm .

Then, the active layer 3 is formed on the first clad layer 2. The conductivity of the active layer 3 is usually a p-type and a material having a band gap smaller than that of the first clad layer 2 is generally used. For instance, in case where the first clad layer 2 is composed of $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$, a Zn-doped GaAs having a carrier density of about 2×10^{17} to $8 \times 10^{17} \text{ cm}^{-3}$ and a thickness of about 0.3 to 2 μm may be formed as the active layer on the first clad layer 2.

A layer having a low carrier density and a high resistance is disposed as a current block layer 4, having a common plane with the active layer, so that the current block layer 4 and active layer 3 are parallel and side by side, preferably with the current block layer 4 adjacent to the active layer 3 and surrounding the active layer 3. In case of using GaAs-based compound, an i-type AlGaAs layer of an indirect transition type at high Al concentration is preferably disposed. The Al-Ga composition may be the same as that used for the first clad layer 2 or the second clad layer 5. Then, it is preferably an i-type material not having dopant added intentionally. The thickness of the current block layer 4 may be identical.

with that of the active layer 3, but is preferably greater than that of the active layer 3. Concretely, the thickness of the current block layer 3 is about from 1 to 8 μm . In this case, if an AlGaAs layer is formed, light confining effect can also be obtained in view of relation with a refractive index.

Then, the second clad layer 5 is formed on the active layer 3 and the current block layer 4. The second clad layer 5 has a conductivity opposite to that of the first clad layer 2 and it has usually a p-type conductivity. The composition of the second clad layer 5 used may be identical with that of the first clad layer 2 except for the dopant so long as the layer has a band gap greater than that of the active layer 3. In this embodiment, the composition of the second clad layer 5 is $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$, the dopant is Zn and the concentration of Zn is about from 5×10^{18} to $3 \times 10^{19} \text{ cm}^{-3}$. The thickness of the second clad layer 5 may be selected optionally within such a range as not hindering light taking-out and it is preferably about from 0.5 to 50 μm .

The second electrode 6 is disposed on the second clad layer 5. In this case, the second electrode 6 preferably has an aperture so that it is present only above the block layer 4 so as not to interrupt light emitted from the active layer 3. The first electrode 7 is disposed on the surface of the substrate 1 opposite to the first clad layer 2. The first electrode 7 on the side not taking out the light undergoes

no such restriction of the second electrode 6. The thickness for each of the first and the second electrodes is preferably from 0.3 to 2 μm .

Further, a light take-out layer may be disposed between the second clad layer 5 and the first electrode 6.

For the method of manufacturing the LED according to the present invention, various methods such as LPE process, MOCVD process, VPE process, MOVPE process or MBE process may be applied, and the MBE process or MOCVD process is preferred in a case of using the Bragg reflective layer.

There is no particular restriction for the order of forming each of the layers so long as the structure according to the present invention can be fabricated. Referring to an example, the first clad layer 2 and the active layer 3 are grown on the substrate in order, and SiN_x is grown thereon by an adequate means. Then, the masking is applied by means of photolithography or the like only to a portion leaving the active layer, and not masked SiN_x is etched. Further, the etching is applied till a portion of the first clad layer 2 is eliminated.

Successively, the current block layer 4 is grown. In this instance, if the current block layer 4 is composed of a composition containing rich aluminum or zinc and is liable to cause deposition of polycrystals on a mask, the supply of a halide gas or the like simultaneously with a material gas for growing is preferred because of preventing occurrence of polycrystals. After the completion of the

growing of the current block layer 4, the mask is removed and the second clad layer 5 is grown thereon to a desired thickness, thereby obtaining the structure according to the present invention.

The LED of the present invention has more excellent light emitting output than that in the prior art.

Since the LED according to the present invention has a higher current density in the active layer and reduced light absorption and reflection as compared with LEDs of the comparative example, the light emitting output, for example, brightness is improved at least 50% as compared with those of the prior arts.

EXAMPLE

Description will be made to the present invention referring to examples but the present invention is not restricted only to the examples.

EXAMPLE 1

An n-type silicon-doped $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ (carrier density: $5 \times 10^{18} \text{ cm}^{-3}$) was grown as a first clad layer by 10 μm in thickness on an n-type GaAs substrate. In the course of the growing, $\text{Al}_{0.1}\text{Ga}_{0.9}\text{As}$ and AlAs were stacked by 10 pairs as the Bragg reflective layer. Then, a p-type Zn-doped GaAs (carrier density: $5 \times 10^{17} \text{ cm}^{-3}$) was grown as the active layer by 1 μm in thickness on the first clad layer. Subsequently, etching was applied by photolithography after

masking a 100 μm -diameter area around the center thereof with SiN_x as a portion used as the active layer. Then, an undoped $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ was grown by 5 μm in thickness as the current block layer and, successively, a p-type $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ (carrier density: $3 \times 10^{19} \text{ cm}^{-3}$) was grown by 20 μm in thickness on the active layer as the p-type second clad layer. Then, a flat pattern of the electrode was disposed such that the electrode covers only portion above the current block layer. Fig. 4 shows a relation between the conducting-current and the light output characteristic of the LED.

COMPARATIVE EXAMPLE 2

An LED was produced with the same structure as that in the Example 1 except for not disposing the current block layer. This structure was the same as that shown in Fig. 3. Fig. 4 shows a relation between the current supplied and the light output characteristic of this LED.

As apparent from the foregoing results, the light output could be increased by about 1.5 times.

CLAIMS

1. A light emitting device comprising:

a first clad layer (2) and a second clad layer (5) formed
5 successively on a semiconductor substrate (1).

an active layer (3) and a current block layer (4) for
current constriction both interposed between said first and
second clad layers (2,5) so as to have a common plane (4).

a first electrode (7) formed on the surface of the substrate
10 opposite to the first clad layer (2), and

a second electrode (6) formed on the second clad layer (5).

2. A light emitting device as defined in claim 1, wherein
the current block layer (4) is adjacent at least a portion of the
15 periphery of the active layer (3).

3. A light emitting device is defined in either one of
claims 1 and 2, wherein the current block layer (4) surrounds the
active layer (3).

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4. A light emitting device as defined in any one of the
preceding claims, wherein the thickness of the current block
layer (4) is greater than the thickness of the active layer (3).

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5. A light emitting device as defined in claim 4, wherein
the thickness of the current block layer (4) is from 1 to 8 μm
and the thickness of the active layer (3) is from 0.3 to 2.0 μm .

6. A light emitting device as defined in any one of the

preceding claims, wherein a Bragg reflective layer (8) is disposed either within the second clad layer (2) or between the second clad layer (8) and the substrate (1).

5 7. A light emitting device as defined in any one of the preceding claims, wherein the first electrode (6) has an aperture at a position above at least part of the active layer (3)

8. A light emitting device is defined in claim 7, wherein
10 the first electrode (6) is formed in a substantially identical pattern with that of the current block layer (4).

9. A light emitting device constructed and arranged substantially as hereinbefore described with reference to Figs.1,
15 3 and 4 of the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9412937.6

Relevant Technical Fields

- (i) UK Cl (Ed.M) H1K (KEAA, KELB, KELS, KELX)
(ii) Int Cl (Ed.5) H01S, H01L

Search Examiner
C D STONE

Date of completion of Search
24 AUGUST 1994

Databases (see below)

- (i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-
ALL

(ii)

Categories of documents

- X: Document indicating lack of novelty or of inventive step. P: Document published on or after the declared priority date but before the filing date of the present application.
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Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0266826 A1 (PHILIPS)	1 at least
X	US 4928285 (TOSHIBA)	1 at least

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